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A Systematic Evidence Review of the Impacts of Climate Change on the Health of Outdoor Workers in Urban Asia

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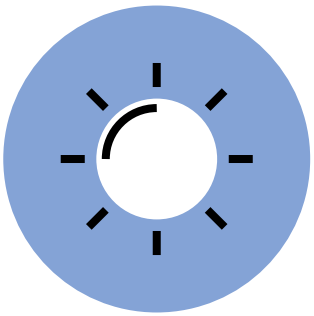
Executive summary



The 2024 Asia-Pacific Human Development Report warns that climate change poses a “profound existential threat” (p.3) for Asia and the Pacific and that it has the potential to disrupt decades of socioeconomic progress.

This systematic evidence review offers a comprehensive synthesis of existing literature on how climate change impacts the health of outdoor workers in rapidly urbanising Asia. Of a total of 734 identified papers, a final set of 18 papers were selected that met the inclusion criteria for the study and those were then subject to data extraction and detailed analysis. The review identifies critical gaps in understanding the direct and indirect health effects of climate-related stressors, such as extreme heat, air pollution, and other weather-related hazards. It also explores adaptation strategies employed by outdoor workers and identifies key areas for future research and policy intervention.

This publication marks the first output of the Wellcome Trust-funded project titled “The health impacts of climate change on precarious outdoor workers in urban megacities in Vietnam”.

Key Findings

- Of the 18 studies reviewed, the majority employed quantitative methods, with nine being exclusively quantitative and eight using mixed methods where quantitative approaches dominated. Only one study relied solely on qualitative methods. Among the mixed-methods studies, qualitative components played a distinctly secondary role. Notably, none of the studies actively engaged target groups in the co-production of knowledge or emphasised participatory approaches.

- Of all climate change-related health risks covered in the literature, physiological impacts, particularly those associated with heat exposure, dominate the evidence base. Heat-related risks – such as heat cramps, heatstroke, and cardiovascular complications – are extensively documented, particularly in high-risk sectors like construction, street vending, and transportation. Outdoor workers face disproportionately high risks due to the nature of their jobs. However, far less attention has been given to other types of health impacts, such as cognitive and mental health effects.
- Air pollution is a key factor in exacerbating health risks for outdoor workers. Pollutants like PM2.5, nitrogen oxides, and sulphur dioxide aggravate respiratory diseases and cardiovascular conditions, particularly for low-income workers who are more exposed due to their daily activities in high-traffic and industrial zones. Studies from countries such as China, Bangladesh, and Myanmar emphasised the need to improve air quality monitoring and interventions to reduce these hazards.
- Outdoor workers in the informal sector and those with pre-existing health conditions are among the most vulnerable to climate change. Construction workers, rickshaw drivers, and street vendors are exposed to multiple stressors, exacerbated by socioeconomic factors such as low income, lack of access to healthcare, and poor living conditions. Older adults, women, and those with pre-existing health conditions face even higher risks of heat-related illnesses and death, underscoring the intersection of climate vulnerability with social inequities.
- Climate-related health impacts among outdoor workers are under-reported. Many workers refrained from reporting symptoms to employers or health authorities due to a fear of job loss, lack of awareness, and inadequate reporting mechanisms. This leads to delayed treatment and exacerbates health risks, particularly for heat-related illnesses, which are often perceived as an unavoidable, and 'natural' aspect of their work.

- While outdoor workers adopt various coping strategies – such as increased hydration, frequent breaks, and shifting work hours – these measures often fall short in protecting against extreme weather. The review finds that structural factors, such as inadequate urban infrastructure and limited access to resources like cooling centres and protective gear, hinder effective adaptation.
- Existing policy frameworks fail to protect outdoor workers from climate-related health risks. The literature emphasises the need for more comprehensive and localised measures, including heat-health warning systems, improved air quality monitoring, and the establishment of occupational safety standards. They also highlight the importance of policies that specifically address vulnerable groups, including informal and migrant workers.

Implications for Research

Interest in the health impacts of climate change on outdoor workers in urban Asia has been growing, but significant knowledge gaps remain. This review highlights the need for further investigation in several areas:

- The impact of hazards other than extreme heat, such as flooding, typhoons, and co-climatic events like landslides on health.
- Evidence suggests that underlying structural factors – such as rural/urban inequalities, informal labour markets, and social inequalities – amplify health vulnerabilities among outdoor workers. These intersections are poorly understood, yet they are critical for identifying effective strategies to reduce climate-related health risks.
- While there is substantial evidence on physiological impacts such as heat stress and cardiovascular complications, far less attention has been paid to the psychological and cognitive effects of climate change on outdoor workers, particularly heat-induced mental health issues.

Implications for Policy

The findings of this systematic review make it clear that outdoor workers in urban Asia are facing mounting health risks associated with climate change. While certain coping strategies are in place, they are scattered, unsystematic and insufficient, highlighting the need for more comprehensive and coordinated policy responses. Establishing region-specific standards, improved health monitoring systems, and targeted educational initiatives are essential to reducing the health impacts of climate change on vulnerable populations.

Moreover, focused education and awareness campaigns are imperative to equip workers with the knowledge to identify climate-related illnesses and seek timely medical intervention. Future research should focus on addressing the gaps identified, with an emphasis on interdisciplinary and mixed-methods approaches that integrate social, economic, and environmental dimensions. In doing so, policymakers and stakeholders can better safeguard the health and wellbeing of outdoor workers in an era of accelerating climate change.

Construction assistants and porters pushing a cart up a slope together under the scorching sun in Da Nang City, a project research site, July 2024. (Source: Truong Minh Den).

1. Introduction

Climate change is one of the greatest public health threats of our time. It is already altering local and regional weather patterns and increasing the frequency and severity of extreme events such as heatwaves, floods, droughts, and wildfires (IPCC, 2023). Rising temperatures have been very widely recorded, with recent years witnessing exceptionally hot summers, a trend for Asia that continued into 2024 (WMO, 2024). Northern India, Myanmar, the Philippines, and Thailand all experienced temperatures in the mid-400°C. Moreover, climate change impacts health in both direct and indirect ways. Direct climate change/health pathways occur due to rising temperatures, flooding and storms that can cause injury and illness, potentially leading to death. Indirect pathways arise when, for instance, changes in precipitation and temperature impact crop yields, affect the epidemiology of diseases and disease vectors, and worsen air quality.[1] These impacts disproportionately affect the poorest countries where governments often lack the capacity[2] to implement and support adaptation measures, and where people have limited adaptive capacity and are therefore particularly vulnerable to the effects of climate change. Among such groups, outdoor workers, many of whom comprise domestic migrants, are particularly exposed to the effects of climate change given the nature of their work, the wider conditions in which they live, and their characteristic social marginality.

This systematic review draws on an expanding body of research on the impacts of climate change on the health of outdoor workers in urban Asia, being the first to provide a comprehensive mapping and synthesis of this literature. It provides a detailed examination of climate change-related health impacts, vulnerabilities, and coping and adaptation strategies of outdoor workers, while also identifying critical evidence gaps that require further research. This review covers a broad range of occupational groups, geographic settings, health outcomes, and adaptation strategies, emphasising the unique challenges faced by outdoor workers in urban Asia.

1. For integrative recent studies of health and climate change see: IPCC 2022, Romanello et al. 2023..

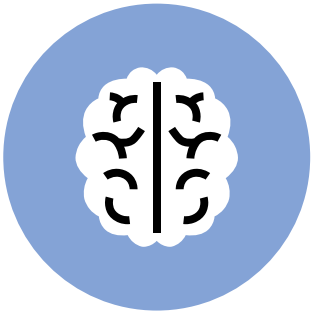
2. We adopt the IPCC's definition of adaptive capacity as the "ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities or to respond to consequences" (https://apps.ipcc.ch/glossary/).

This publication marks the first output from the Wellcome Trust-funded project titled “The health impacts of climate change on precarious outdoor workers in urban megacities in Vietnam”. The project focuses on the (in)visible vulnerabilities and multiple health exposures of such workers in Vietnam, a country experiencing rapid urbanisation and characterised by a significant informal sector. By addressing fundamental knowledge gaps and co-constructing a new evidence base through a multi-stakeholder approach, this project aims to transform our understanding of the exposures and vulnerabilities faced by outdoor urban workers. It also seeks to enhance the capacity of Vietnamese policy makers to devise interventions attuned to the conditions and concerns of workers.

The rest of this report is organised as follows. Chapter 2 provides a brief overview of the methodology (see Annex A for details). Chapter 3 presents the findings from the evidence review, while Chapter 4 highlights gaps in the literature, discusses implications for research and policy, and outlines directions for future research.

Project researcher interviewing a porter at a wholesale market in Ho Chi Minh City, July 2024 (Source: SocialLife Research Institute, our project local partner in Vietnam).

2. Methodological Approach



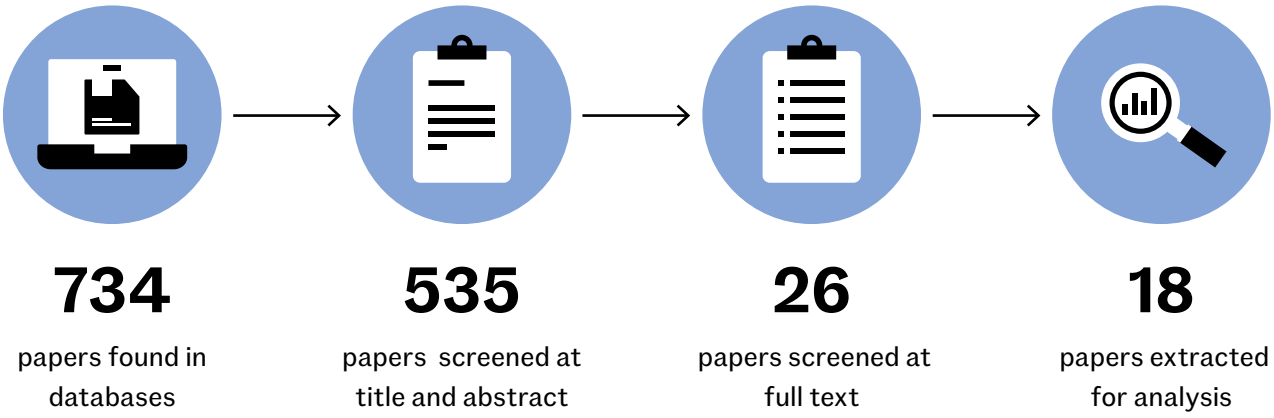
This systematic evidence review examines the state of knowledge on the health impacts of climate change on outdoor workers[3] such as porters, construction workers, street vendors, and motorcycle taxi drivers in urban Asia. Conducted between February and June 2024, this review captures the available evidence from English language, peer-reviewed publications. We focus exclusively on urban Asia, as significant systematic reviews on the general climate change-health nexus at the global level already exist (see Berrang-Ford et al., 2021; Romanello et al., 2023). It provides the regional context in which to examine the impact of climate change on the health of outdoor workers in Vietnam's megacities.

The systematic evidence review followed a five-stage process: 1) Development and testing of search strings related to two broad areas: climate change and climate variability; and health and health outcomes. 2) Screening papers based on content, types of literature, date of publication, geography, and language using screening criteria developed for this purpose. 3) Piloting search terms to test the strength of our search strings and inclusion and exclusion criteria across four databases: Google Scholar, Scopus, PubMed, and Web of Science. 4) Based on these preliminary test searches, we refined our search terms where necessary and then applied these revised terms to conduct comprehensive database searches on Scopus, Web of Science, and PubMed. We then screened the results for relevant evidence. 5) Data extraction. More details on the systematic evidence review methodology are provided in Annex A.

3. Many studies (e.g. Cioffi et al. 2012, Rocholl et al. 2020, Ward et al. 2024) do not actually define 'outdoor workers', presumably for the reason that it is self-evident: they are those who labour in the open air. But, and to be clear, in this paper we define 'outdoor workers' as those whose work characteristically (but not exclusively) requires them to labour in the open air. Some work may be undertaken indoors or undercover: porters may be working in warehouses and construction workers inside part completed buildings, for example. But in the most part the nature of the work determines that it is pursued outdoors. Given that it is the demands of the work that determines its outside location, we hone in on four areas of urban outdoor work: portering, construction work, street vending, and motorcycle taxi driving. (The largest single group of outdoor workers is farmers. While in urban areas farmers are less prevalent, there is some urban farming, especially in peri-urban zones [see Nguyen et al. 2021], and such farming is a particular characteristic of Asia's extended metropolitan regions.)

Using the year 2000[4] as the starting point for the review and the search strings available in Annex A, 734 papers were identified in databases. After removing duplicates, the team identified 535 papers for title and abstract screening. Based on inclusion and exclusion criteria for these 535 papers, the review was narrowed down to 26 papers for full manuscript review. After screening the full text of all 26 papers against further inclusion and exclusion criteria, 18 papers finally proceeded to systematic evidence review. Ultimately, these 18 articles were extracted from and assessed in a tabular form summarising themes, subthemes, research questions, and other sections that were relevant for assessment, including health impacts, types of extreme weather impacts, forms of outdoor working, coping strategies, and policy recommendations.

Figure 1. Flow diagram of the screening process



4. We chose the year 2000 as the starting point for our review because the majority of research on the health impacts of climate change on outdoor workers emerged after this time. A review of IPCC reports and literature searches in major databases revealed that climate change-related studies significantly increased from 2000. Prior to this, there were very few studies addressing these issues, with minimal relevant research found in searches from 1990 to 2000.

A scrap collector working near an outdoor market in Da Nang City, a project research site, July 2024. (Source: Project photo).

3. Literature review findings

Drawing on a detailed analysis of the papers selected for this review, we present findings in this section. Those can be grouped into three categories. First, as related to methodological approaches used to research the intersection between climate and health. Second, as related to recurring themes on the health effects of climate change, existing visible and invisible vulnerabilities of outdoor workers, climate adaptation, and coping strategies. Third, as related to existing support structures and policy responses. A detailed summary of the 18 papers reviewed can be found in A6 of Annex A.

3.1. A focus on “heat” dominates the literature

Figure 2 presents a word cloud that visually represents the frequency of terms, reflecting the key themes and concerns within the literature. This word cloud is a visual summary of a content analysis, derived from data extracted using a standardised data extraction tool. It clearly shows the primary areas of focus, revealing which terms – and thus themes – are most prevalent. For example, the term ‘heat’ stands out as the dominant concern, significantly outweighing other extreme weather (such as typhoons, hurricanes, cyclones, storms and floods), all of which were also included in our search strings.
The prominence of heat signals a central focus on the effects of rising temperatures, driven by climate change, particularly on individuals engaged in outdoor occupations. In contrast, other weather extremes and their impacts – such as flooding – receive relatively less attention in the literature surveyed here.

Figure 2: Word Cloud

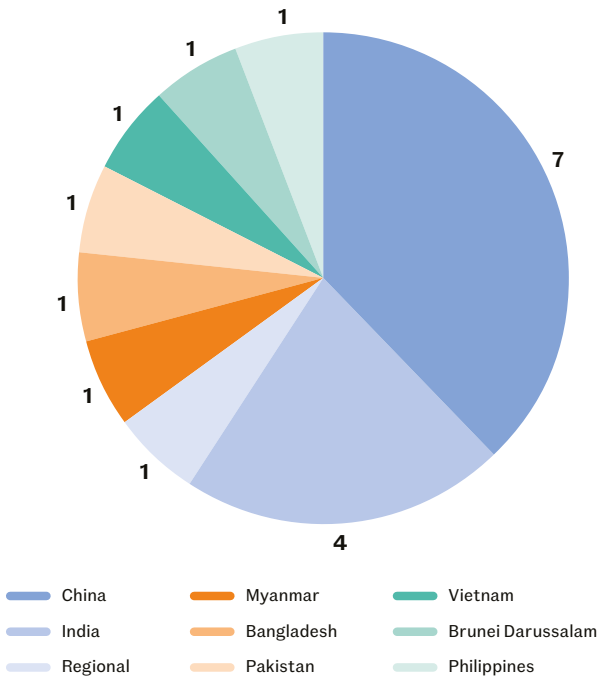
Source: Authors' synthesis.

The word cloud also highlights six intersecting groups of terms that constitute much of the remaining content. First, there are terms related to the unequal social distribution of risk: 'exposure', 'vulnerability', 'vulnerable', and 'risk' itself. Second, the word cloud picks out the health-related impacts of extreme weather, with terms such as 'mortality', 'stress', 'symptoms', and 'illnesses'. Third, there are words that link to our focus on outdoor employment: 'work' and 'outdoor'. Fourth, there are geographical terms – 'urban', 'city', 'China', and 'India' – which underscores the review's focus on urban areas in Asia, particularly in countries undergoing rapid urbanisation and home to large populations of outdoor workers. Fifth, the word cloud identifies environmental terms, such as 'pollution', 'air', 'haze', and 'weather', that are central to the study. Finally, it includes terms related to adaptation in policy, practice and among outdoor workers: 'adaptive', 'policy', 'capacity', and 'strategies'.

3.2. From region to nation: the dominance of studies on China and India

The 18 papers extracted for detailed review are unevenly distributed across Asian countries, highlighting where attention has hitherto been directed and therefore gaps in current research. While China (with 7 papers) and India (with 4 papers) are well-represented, with multiple studies focusing on the health impacts of climate change on outdoor workers (Cheng and Huang, 2019; Yin and Wang, 2017; Dutta et al., 2015), attention dedicated to this topic for other countries, including Vietnam, is limited (see Figure 3, and A6 of Annex A). This reflects the emerging status of the field – such that unevenness is likely as studies will be based on quite a narrow research base – and indicates where research capacity and attention are greatest. It suggests a need for a research agenda that consciously identifies regional gaps and does not assume that research undertaken in a subset of countries will capture the full spectrum of climate change impacts on outdoor workers in different geographic, socioeconomic, policy and environmental contexts. Care needs to be taken to treat national and local contexts as potentially distinct and different in terms, for example, of patterns of vulnerability, degrees of adaptation, and effectiveness of policy interventions. In short, we cannot assume the likely effects of climate change on the health of outdoor workers in one country, based on evidence drawn from another.

Figure 3: Geographical distribution of identified studies (number of papers)



3.3. There is a prevalence of quantitative and mixed-method approaches over qualitative studies

Of the papers, 11 collected primary data while seven utilised existing datasets. In terms of methodological approach, nine were quantitative studies, one was qualitative, and eight used mixed-methods. These different approaches reflect disciplinary tendencies and the thematic focus of each paper (see A6 of Annex A).

Quantitative studies provided valuable insights into the epidemiology and prevalence of health effects (Li et al., 2021; Cheng and Huang, 2019). At the same time, they often fall short in exploring the underlying social, cultural, and behavioural factors that shape vulnerability and adaptation strategies among outdoor workers. Mixed-methods studies offered a different perspective, contextualising the health impacts of climate change within the social and cultural frameworks that influence these workers' vulnerabilities and adaptative responses (Lohrey et al., 2021; Dutta et al., 2015). Complementing these approaches, a single qualitative study (Ko et al. 2020) offers detailed insights into the diverse physical and social contexts of informal workplaces in Myanmar.

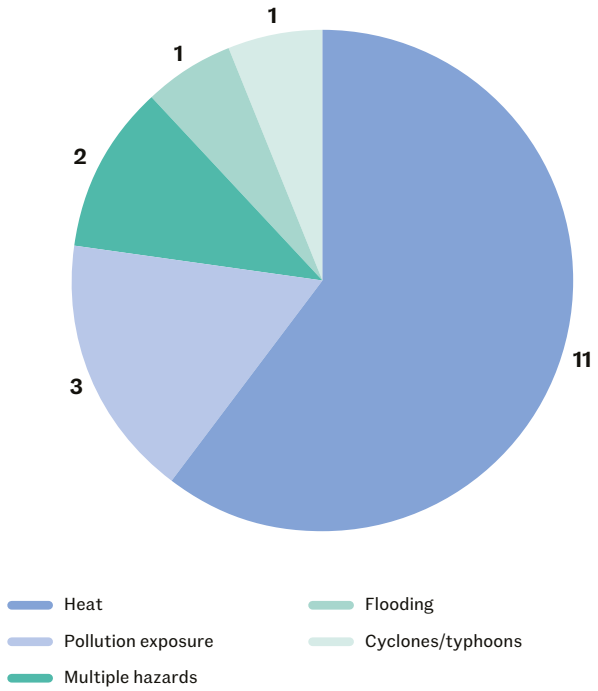
While assembling quantitative data so that the effects of climate change on health can be assessed is important – not least because such evidence has traction with policymakers – the need to understand why, where, who and how such impacts manifest requires the generation of a qualitative understanding of the climate – health – vulnerability nexus. These two bodies of evidence, quantitative and qualitative, are complementary, serving different tasks.

3.4. For outdoor workers, vulnerability caused by heat and air pollution is intersectional and multidimensional

The identified studies recognise outdoor workers as one of the most vulnerable and exposed groups to the effects of climate change, alongside elderly people, women, low-income social groups, people with pre-existing illnesses and conditions, and those living in urban and/or high population density areas (Cheng and Huang, 2019; Yin and Wang, 2017; Li et al., 2021; Liu et al., 2019; Yu et al., 2023; Knowlton et al., 2014; Odihi, 2001). Acute vulnerability arises where these identified vulnerable groups and their living conditions intersect with outdoor working. For example, a study of the health and wellbeing of street vendors in Yangon, Myanmar, demonstrates that extreme weather effects were acutely demanding for pregnant and elderly street vendors (Ko et al, 2020). The study argues that poor working conditions undermined the physical health of those subgroups of street vendors who went through life transition events affecting their health. Additionally, the study shows that street vendors who had low and fluctuating income could not afford to take sick leave when they were ill, and this put them in an even more precarious position than those with more secure and stable income (ibid.).

The papers reviewed reveal a wide range of health impacts experienced by outdoor workers due to extreme weather events, with a particular emphasis on heatwaves and outdoor pollution, which we elaborate upon further in 3.4.1 and 3.4.2 respectively (Figure 4). Heat-related illnesses such as heatstroke, heat exhaustion, and heat cramps are documented across multiple studies (Dutta et al., 2015; Li et al., 2021), highlighting the acute physiological risks posed by prolonged exposure to high temperatures in outdoor occupational settings. Additionally, the association between outdoor air pollution and respiratory diseases, cardiovascular problems, and other adverse health outcomes underscores the interconnectedness of environmental and occupational health hazards faced by outdoor workers (Khan et al., 2023; Yu et al., 2023). The severity and diversity of these health effects emphasises the urgent need for targeted interventions, including heat-health warning systems, air quality monitoring, and workplace regulations, to protect the health and wellbeing of outdoor workers in the face of climate change.

Figure 4: Different environmental impacts on the health of outdoor workers in identified studies (number of papers)



While heat-related health effects and the connections between heat and pollution are well represented in the studies – comprising 11 of the 18 papers – the health impacts of other climatic hazards such as flooding and cyclones are less frequently discussed in the literature. There is a case for closer consideration of co-climatic hazards (or cascading hazards) such as landslides (Paul et al., 2019) and fire-related haze (Odihi, 2001), and their health impacts. Similarly, there is a need to explore the role of compound weather extremes (see Li et al., 2021) where the combination of hot days with hot nights appears to accentuate health impacts.

Female construction worker wearing a traditional conical hat working on a building site between two partially constructed walls in Ho Chi Minh City, a project research site, May 2024. (Source: Project photo).

3.5. Heat has both direct and indirect impacts on health

The most prevalent and recurring theme identified in the literature was the impact of heat on outdoor workers. Eleven studies identified direct and indirect impacts of heat-related events on the health of outdoor workers (Figure 5). First, the studies explored epidemiological impacts including mild and severe health symptoms related to heat stress. Second, the studies examined risks of work-related injuries, which were caused by heat exposure. Third, the studies observed that prolonged heat exposure increases the number of hospital admissions and the risk of mortality among outdoor workers.

Figure 5: The types of impacts of heat-related events on health of outdoor workers

Epidemiological impacts | Work-related injuries | Hospital admissions and mortality

Epidemiological Impacts

Dutta et al. (2015) surveyed construction workers in India and found that heat stress exposure significantly impacted the health of outdoor construction workers. The survey results found that, in the summer period, 59% of construction workers self-reported mild or severe health symptoms related to heat stress, including heavy sweating, dehydration, headache, loss of coordination, dizziness, blurred vision, fainting, spasms, abdominal cramps, and weakness/fatigue (Dutta et al., 2015). Similarly, a study by Li et al. (2021) in China highlighted the vulnerability of outdoor workers to extreme heat, with prolonged exposure leading to heat stress and conditions such as heatstroke, heat cramp, and acute cerebrovascular accidents. In Hanoi, Vietnam, Lohrey et al. (2021) examined self-reported heat-related symptoms of outdoor workers and grouped them into three types: heat cramps, heat exhaustion, and heat stroke. Between 58% and 70% of respondents reported heat cramps while 65% of informal street vendors and 40% of builders and shippers indicated symptoms of heat exhaustion. Other frequently reported health impacts included tiredness, sweating, thirst, feeling hot, headache, and dizziness (Lohrey et al, 2021).

Work-related injuries and mortality

Some studies indicate that heat increased the risks of work-related injuries among outdoor workers (Cheng and Huang, 2019; Sheng et al., 2018). The injuries were a result of a combination of physical and behavioural factors, such as heat stress and heat stroke, fatigue, dizziness, sweaty hands, foggy glasses, and hot tools. Based on the analysis of workers' compensation claims in Guangzhou, China, during 2011-2012, Sheng et al. (2018) determined that high temperatures were significantly associated with work-related injuries; for every 1°C rise of maximum daily temperature, the number of injury claims increased by 1.4%. Another study conducted in Guangzhou, China, analysed data from government departments and concluded that, during heat waves, the risk of injury increased by 50% among outdoor workers employed in the transport and construction sectors (Cheng and Huang, 2019).

Heat extremes were also found to be associated with increased hospital admissions. During extremely high temperature periods, ambulance dispatches increased by 19% in Shenzhen, China, while hospital admissions in the Mekong Delta, Vietnam, rose by 6.1% (Cheng and Huang, 2019). They found that increased temperatures due to climate change exacerbate heat-related illnesses, such as heat stress and heatstroke, particularly among construction workers and street vendors (Cheng and Huang, 2019).

Knowlton et al. (2014) reveal that extreme heat is an underappreciated public health hazard, with excess mortality of 30% associated with the heatwaves of 2010 in Ahmedabad, India. Outdoor workers, such as construction labourers and rickshaw drivers, are identified in the paper as particularly vulnerable due to prolonged exposure to high temperatures, with an estimated 10% hospitalised at least once during the summer for heat-related health issues. These workers – who are disproportionately poor and more likely to be recent migrants lacking social embeddedness – experience greater challenges in accessing healthcare. Their access to cooling resources, such as air conditioning, is also significantly reduced.

Compared to physical health, the cognitive and mental health implications of extreme heat remain relatively underexplored in the papers reviewed here, a gap also noted by authors such as Lee et al., (2023). An exception is Liu et al.'s (2019) study in Jinan, China, which explores the impacts of heat waves – defined as daily maximum temperatures exceeding 35°C for at least three days – on hospital visits for mental health conditions in 2010. This study found a significant association between high temperatures and increased mental health issues among outdoor workers, including schizophrenia, classification disorders, delusional disorders, and mood disorders. Outdoor workers were particularly vulnerable to these conditions, with extreme heat exacerbating the risk.

Lohrey et al. (2021) focused the physical health risks associated with heat exposure, including heat cramps, heat exhaustion, and heatstroke. Their analysis of 1,027 outdoor workers surveyed in Vietnam in 2018 revealed that older workers with pre-existing health conditions and women were more susceptible to physical health issues. The findings showed that each additional year of age increased reported symptoms by 0.016 and the likelihood of doctor visits by 2.8%. Women participants were 50% more likely than men to report heat-related health impacts. Furthermore, 48% of workers reported that heat stress had led to a loss in income, with those caring for children under five and homeowners 50% more likely to report this impact. While behavioural adaptations, such as frequent breaks, seeking shade, and hydration were observed, these measures often proved insufficient to fully mitigate heat-related health problems. This indicates the need for more comprehensive protective measures and policies to reduce the physical and mental health risks posed by extreme heat.

The studies show that prolonged heat exposure increases the risk of mortality among outdoor workers (Yin and Wang, 2017; Li et al., 2021; Yu et al., 2023). Research by Yin and Wang (2017) in Beijing, China, found that exposure to extremely high temperatures raised the risk of mortality from cardiovascular disease, with outdoor workers being particularly vulnerable. For instance, when the daily temperature exceeded 33°C for ten consecutive days, the excess mortality risk for outdoor workers increased by 149%, compared to 87% for the general population. Li et al. (2021) analysed the impacts of compound heat extremes – defined as consecutive occurrences of a hot night and a hot day within 24 hours – on outdoor workers in Guangzhou City, China. The study concluded that these conditions increased mortality risk significantly, with outdoor workers facing a higher risk than the general population. Similarly, Yu et al. (2023) conducted research in Jining City, China, and observed that exposure to extremely high temperatures between 2019 and 2021 led to increased mortality rates among residents, with outdoor workers being at the greatest risk. On average, there were nine deaths per day among outdoor workers during high-temperature periods. For every 1°C rise within the temperature range of 24.4–32.3°C, the non-accidental mortality rate for the Jining City residents increased by 0.58%.

A street vendor navigating a flooded street after heavy rain in Ho Chi Minh City, September 2024. (Source: SocialLife Research Institute project team).

3.6. Environmental pollution is a health hazard for outdoor workers

Outdoor workers in urban Asia are not only exposed to heat but also face significant health hazards from environmental pollution. Several studies explored these impacts, highlighting the compounded health risks due to the interaction of air pollution and extreme heat events. Air pollution caused by human activities such as transportation, industry, and fossil fuel burning contributes to trapping heat in the atmosphere and worsening global warming. The studies included in this review indicate that the interactions between air pollution and extreme heat events increase public health risks (Cheng and Huang, 2019), particularly affecting low-income outdoor workers who endure substantial exposure to pollutants and extreme temperatures. These findings highlight the critical need for interventions to mitigate the adverse health effects of outdoor pollution on vulnerable populations.

Odihi's (2001) study of haze episodes, which were connected to drought and forest fires between 1997-1998 in Brunei Darussalam, indicated an increasing number of health problems related to bronchial disorders or chronic obstructive pulmonary diseases, including asthma, bronchitis and emphysema. The survey findings show that during haze episodes the frequency of asthma attacks among people previously diagnosed with asthma increased by 30% while new asthma cases grew by 11% (Odihi, 2001). Similarly, a study in Bangladesh by Khan et al. (2023) found that exposure to outdoor pollution increased the risks of respiratory disease, asthma incidence, and cardiovascular disease, and outdoor workers were particularly at risk of developing these illnesses. The research examined air quality data in Dhaka, Narayangonj, and Gazipur and showed that Dhaka had higher concentrations of gaseous pollutants, such as nitrogen oxides, CO, and O3, while Narayangonj had a higher frequency of PM2.5 and PM10 (Khan et al, 2023). Low-income outdoor occupations were most vulnerable to exposure to high levels of particulates, with the authors listing construction workers, rickshaw pullers, compressed natural gas drivers, and street vendors as examples (ibid.).

In Yangon, Myanmar, Ko et al. (2020) observed similar vulnerability among street vendors who were frequently exposed to vehicular fumes and pollution in heavy traffic areas. Additionally, their use of charcoal for cooking exposed them to harmful smoke and toxic chemicals, contributing to a range of health issues, including respiratory infections, chronic obstructive pulmonary disease, lung cancer, tuberculosis, asthma and cardiovascular disease, with elevated mortality (Ko et al., 2020).

A study by Yu et al. (2023) in Jining City, China examined the effects of pollutants such as PM2.5, SO2, and NO2 on non-accidental deaths from 2019 to 2021. Outdoor workers faced higher risks than indoor workers, particularly during winter. Seasonal variations in pollutant concentrations were consistent with their impact on mortality, with NO2 showing the greatest effect. For every 10 μg/m^3 increase in NO2, the relative risks of mortality were 1.11 in spring, 1.02 in summer, 0.97 in autumn, and 1.19 in winter.

3.7. Some outdoor workers are more vulnerable than others

Specific occupational groups in urban Asia, such as construction workers, street vendors, motorcycle taxi drivers, gas cylinder delivery drivers, boat coxswains, and farmers, are identified in the studies as being particularly vulnerable to climate change-related health risks, highlighting the unequal distribution of risks (Paul et al., 2019; Dutta et al., 2015). These groups face elevated risks and vulnerabilities due to varying exposure levels, socioeconomic status, access to protective measures, and the nature of work activities.

Certain demographic groups are more vulnerable to heat- or weather extremes-related health impacts. Studies show that older adults and those with chronic respiratory conditions and underlying health conditions, such as cardiovascular diseases, diabetes, and other chronic illnesses, are at higher risk of adverse health effects during heatwaves (Lohrey et al., 2021). These conditions compromise the body's ability to regulate temperature and

Two male construction workers, barefoot, deliver a heavy load of gravel through a narrow alley in Da Nang City, May 2024 (Source: Anh Ngoc Vu).

cope with heat stress, increasing susceptibility to heat-related illnesses and mortality (Lohrey et al, 2021). Socioeconomic factors, such as income level, educational attainment, and access to resources significantly influence vulnerability. Lower-income groups often have limited access to protective measures and healthcare services, which exacerbates their susceptibility to heat-related illnesses.

Studies indicate varying vulnerability levels according to gender, with women often experiencing higher morbidity and mortality risks during heatwaves compared to males (Li et al., 2021; Ko et al., 2020). Physiological differences, such as higher core body temperatures in women, can contribute to this increased vulnerability (Li et al., 2021). A qualitative study of street vendors in Yangon, Myanmar, showed that extreme weather was highly challenging for pregnant workers who continued to work in order to survive (Ko et al., 2020). Furthermore, there exists a notable scarcity of publicly accessible information pertaining to heat-related health risks during pregnancy (see Stassen et al., 2024).

Vulnerability to heat-related illnesses also varies across different geographical locations and spatial settings. Urban areas, characterised by higher population density and urban heat island effects, often exhibit increased vulnerability compared to rural areas. Spatial heterogeneity in vulnerability is also observed within urban settings, with certain neighbourhoods or districts being more prone to heat-related health impacts (Lohrey et al., 2021; Li et al., 2021).

Cheng and Huang (2019) identify the intersectional nature of vulnerability wherein factors such as age, the nature of work, and health conditions, have layered effects. For instance, older workers or those with pre-existing health conditions experience exacerbated impacts. Outdoor workers in sectors such as transportation and construction face increased injury risks during hot days. Tailored interventions and policies are needed to address the unique challenges faced by different occupational groups in specific localities, including provision of protective equipment, implementation of heat-health action plans, early warning systems, and promotion of adaptive strategies to reduce exposure and mitigate health risks (Chen and Huang, 2019).

Lohrey et al. (2021) surveyed 1,027 outdoor workers, including street vendors, builders, and shippers, in Hanoi, Vietnam, to examine the health impacts of heat exposure. The study identified poverty as an underpinning explanatory factor, driving people into such work where they are exposed to heat. It highlighted that vulnerabilities to extreme heat are influenced not only by environmental conditions but also by deeply interconnected socioeconomic and demographic factors. Given that this topic is under-researched, this paper is cited frequently due to the limited research available on this topic. Its large dataset and relevance to our key research questions have made it a

significant reference for understanding the interplay between heat exposure, health outcomes, and broader social determinants in vulnerable populations.

The paper reports that in urban settings like Hanoi, outdoor workers face heightened risks due to prolonged exposure to high temperatures, exacerbated by factors such as inadequate housing with limited access to cooling technologies like air-conditioning. Demographic factors such as age and gender also play crucial roles in shaping heat vulnerability, with older workers and women reporting more heat-related symptoms than other adults. Surprisingly, some occupational groups like construction workers, despite being exposed to significant heat stress, reported fewer symptoms – a finding the authors attribute to potential under-reporting or different coping strategies that were perhaps linked to their younger age and physical health (Lohrey et al., 2021). The study also showcased the limited effectiveness of certain mitigation measures. For instance, access to air-conditioning in bedrooms did not significantly reduce heat impacts, primarily due to the high costs of cooling and the informal nature of many workers' housing arrangements (Lohrey et al., 2021). Moreover, while increasing water intake during hot weather is commonly recommended, the study found that this did not alleviate heat symptoms and, paradoxically, was associated with higher reporting of symptoms. This discrepancy suggests that broader systemic factors, such as inadequate access to sanitary facilities for women, might inhibit effective hydration practices among certain groups (Lohrey et al., 2021).

At the same time, Lohrey et al. (2021) highlighted the role of knowledge and awareness in shaping responses to heat stress. Workers who were more informed about heat exhaustion symptoms and checked weather forecasts were more likely to report health impacts and seek medical attention when necessary. This stresses the importance of targeted education campaigns and accessible information channels, tailored to the specific needs and preferences of different demographic groups. Studies indicate that such resources are often lacking, and not just in low- and middle-income countries. In the USA, for instance, the "presence of web-based pregnancy heat health information is infrequent and limited in content" (Stassen et al., 2024, p.1) and improving access to such "preparedness information regarding heat health and pregnancy could mitigate the negative effects that extreme heat can have on maternal and child health" (Stassen et al., 2024, p.7). Overall, identifying how factors – social, occupational, and geographic – inter-relate is key if interventions are to be appropriately targeted. Unravelling this nexus of relations shows the multifaceted nature of societal vulnerabilities and resilience to climate change-related health risks and coping strategies. Effective mitigation strategies must address these diverse dimensions, incorporating targeted interventions that consider demographic, socioeconomic, occupational, and geographical disparities to enhance resilience and reduce the health impacts of extreme weather events.

3.8. Coping strategies and adaptation of outdoor workers

Studies highlighted the interplay between occupational health, environmental stressors, and adaptation strategies among outdoor workers (Wu et al., 2022; Liu et al., 2019)[5]. Factors such as education, length of residence, access to green spaces, and government interventions play significant roles in shaping adaptive capacity. What influences adaptive capacity, however, is not well understood. Wu et al.'s (2022) study of variations in adaptive capacity to heat in Xiamen, China, for example, reveals a complex set of relationships between adaptive capacity and work, education, income, place of residence, length of residence, and access to green spaces. Liu et al (2019) observed that workers often resorted to behavioural adaptations to mitigate the effects of heat. Common strategies included taking frequent breaks, seeking shade, and ensuring adequate hydration. While these measures provided some relief, Liu et al. (2019) found that they were often insufficient to prevent heat-related health issues entirely. The reliance on such adaptations highlights the lack of systemic measures in place to protect workers from extreme heat. The insufficiency of these personal strategies suggests the need for more

Local project researchers interviewing construction workers at a construction site, where their workspace also serves as their resting and sleeping area, Hanoi, August 2024. (Source: Project team in Hanoi).

5. We adopt the IPCC definition of adaptation in human systems as "the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities" (https://apps.ipcc.ch/glossary/).

comprehensive solutions, including improved workplace regulations and infrastructural changes to reduce exposure to heat and other extreme weather conditions. There is a particular need to identify adaptive capacity or lack thereof among more vulnerable, and often less visible, social groups. Equally, it is important to understand why some otherwise vulnerable groups have been able to reduce their exposure.

Various studies have examined the coping strategies these workers employ to mitigate risks of extreme heat and environmental pollution; these are explored below (e.g., Liu et al., 2019; Khan et al., 2023; Knowlton et al., 2014; Wu et al., 2022).

Hydration and rest breaks

Maintaining hydration and taking frequent rest breaks are fundamental strategies employed by outdoor workers to combat heat stress. Liu et al. (2019) document that workers in urban China regularly took breaks and consumed significant amounts of water. Despite these efforts, the prevalence of heat-related illnesses such as heat exhaustion and heatstroke remained high. Research indicates a persistently high incidence of heat-related illnesses among construction workers and street vendors, despite their adherence to hydration protocols (Liu et al., 2019; Khan et al., 2023). This continued prevalence of heat-related illnesses reveals the limitations of hydration alone as a coping strategy for mitigating the risks posed by extreme heat.

Protective clothing and equipment

The use of protective clothing and equipment is another widespread strategy. In Bangladesh, Khan et al. (2023) observed that outdoor workers frequently used protective gear to shield themselves from pollutants. However, the effectiveness of this approach was limited. Research also highlights a paradox where protective clothing can reduce exposure to pollutants but also exacerbate heat stress due to the use of thick, non-breathable materials (Knowlton et al., 2014).

Seeking shade and altering work hours

Seeking shade and adjusting work hours to avoid peak heat periods were also common strategies. Knowlton et al. (2014) report that outdoor workers in Ahmedabad, India, often adjusted their schedules to work during cooler parts of the day. This approach is linked to a reduction in heat-related illnesses when workers avoid peak temperature periods (ibid.). However, this strategy is not universally feasible, especially for occupations where the nature of the work limits the ability to adjust schedules or reduce workload intensity. For example, Ko et al. (2020) studied street vendors in Yangon, Myanmar, and found that many worked from the early morning (4-6 AM) to nighttime (7-8 PM), leaving little opportunity to avoid the hottest hours.

Community-based support and education

Community-based support and educational initiatives play a critical role in enhancing individuals' coping strategies in urban environments (Knowlton et al., 2014; Wu et al., 2022). For instance, Knowlton et al. (2014) found that street vendors who participated in community health programmes, such as the Heat-Health Action Plan (HHAP) implemented in Ahmedabad, India, demonstrated increased knowledge of effective coping mechanisms and were more likely to adopt them. These programmes provided targeted interventions, including early warning systems, public health messaging, and community engagement. The public health messaging component focused on educating vendors and the broader public about the dangers of extreme heat and offering practical advice on how to stay safe, such as hydration and avoiding peak heat hours. Community engagement required actively involving local stakeholders – such as health workers and community leaders – in outreach efforts, ensuring that heat warnings and coping strategies were widely understood and accessible. As a result, vendors adopted strategies such as seeking shade, staying hydrated, adjusting work hours, and responding proactively to heat alerts to reduce heat exposure. The study by Wu et al. (2022) indicates that educational interventions aimed at increasing awareness of heat and pollution risks, combined with community support such as access to cooling centres and green spaces, result in better health outcomes and more effective management of heat-related challenges.

Built environment and adaptive capacity

The built environment, including green spaces and cooling services, is essential for strengthening heat adaptive capacity (HAC) in urban settings (Wu et al., 2022). Wu et al. (2022) emphasise the importance of amenities provided by local authorities and community groups, such as green spaces and street sprinkling, in improving residents' ability to cope with extreme heat. Green spaces help mitigate the urban heat island effect by providing shaded areas that cool the environment while also offering additional health benefits, thereby contributing to improved individual HAC. Street sprinkling, an effective measure for reducing surface urban heat islands, contributes to a cooler and healthier living environment, particularly benefiting outdoor workers who are most exposed to extreme temperatures. These interventions at various levels of authority, including municipal planning and community-driven initiatives, demonstrate the importance of a well-designed built environment in fostering resilience against climate-related health risks.

Technological interventions

Technological interventions are emerging as effective coping strategies. Yu et al. (2023) highlighted the use of mobile health applications in China to monitor environmental conditions and personal health metrics in real-time. These technologies enabled workers to make informed decisions about when to seek shelter or hydrate. The data point to the potential of these interventions, showing a correlation between the use of technology and a reduced incidence of heat-related illnesses.

3.9. Under-reporting and awareness challenges

The under-reporting of health-related issues among outdoor workers presents a significant barrier to accurate surveillance and effective intervention, influenced by a range of factors at work (Dutta et al., 2015; Wu et al., 2022; Lohrey et al., 2021). To begin with, workers may choose not to report injuries to supervisors, because they fear adverse consequences from their employer (Dutta et al., 2015). Second, a lack of awareness exacerbates the issue. Many workers do not recognise the early symptoms of heat-related illnesses – such as dizziness, excessive sweating, and confusion – as serious health concerns. This leads to delayed treatment with heightened health implications. Lohrey et al. (2021) explored the heat-health impacts reported by various groups of outdoor workers including vendors, builders, and shippers in Hanoi, Vietnam, and found that the increased awareness of heat-health impacts was associated with a higher likelihood of reporting symptoms and seeking medical care. Notably, older workers and women were more likely to report heat-related symptoms. In contrast, younger construction workers were less inclined to report symptoms, often rationalising that they were "used to heat" (Lohrey et al, 2021, p.7).

Inadequate reporting mechanisms also hindered the accurate recording of heat-related illnesses. In many cases, there was no straightforward or confidential way for workers to report their symptoms, and systematic tracking of heat-related health issues by employers or health authorities was often lacking. This was evident in the studies that emphasised the need for establishing robust reporting systems (Wu et al., 2022). Where workers did not trust systems to be robust and confidential then the fear of negative consequences from employers played a role in discouraging workers from reporting illnesses.

Cultural and social barriers also played a role in under-reporting. In some communities, there was a stigma associated with admitting health problems or taking breaks during work, which discouraged workers from acknowledging their symptoms or seeking help. Cultural expectations often normalised harsh working conditions which were endured without complaint (Lohrey et al., 2021). Dutta et al. (2015) found that construction workers in India did not report work-related injuries due to a perception that such injuries were an inevitable part of their jobs.

The differential reporting patterns among various demographic groups highlight the complex interplay between sociocultural factors, occupational norms, and individual perceptions of risk and vulnerability. Wu et al. (2022) found that less educated residents in Xiamen, China, indicated stronger heat adaptive capacity than their more educated counterparts, who had more knowledge about heat-related health impacts. However, outdoor workers reported strong adaptive capacity to heat waves but significant under-reporting of symptoms due to their perception of being accustomed to the heat.

Addressing these challenges requires comprehensive education programmes tailored to the specific needs and circumstances of outdoor workers. Improved awareness and education initiatives, including heat-health education programmes and targeted outreach efforts, are needed to overcome barriers to reporting and ensure that outdoor workers receive timely information, resources, and support to protect their health and wellbeing in the face of climate change. While the physical health impacts of extreme heat are relatively well documented in existing studies, even if the root causes of vulnerability remain less well understood, mental health impacts remain under-reported by workers. Liu et al.'s (2019) study in Jinan, China, was the only identified paper that included data on the relationship between heat exposure and mental illness.

3.10. Policy and support needs for outdoor workers amid climate challenges

A few reviewed studies suggested that climate change will continue to contribute to negative health effects for urban populations due to the rapidly warming climate, other climate extremes, urban expansion, and population ageing (Cheng and Huang, 2019; Li et al, 2021; Knowlton et al., 2014). Among the literature reviewed were papers that included recommendations for future policy interventions to address the adverse impacts of climate change events on public health (Table 1).

Table 1: Policy recommendations

Policy field	Policy detail	Studies
International standards and their monitoring	Setting of appropriate international heat exposure standards for outdoor working	Dutta et al., 2015; Yin and Wang, 2017; Cheng and Huang, 2019
	Implementation and effective monitoring of standards	Dutta et al., 2015
	Heat alerts during extended duration heat waves	Yin and Wang, 2017
Context sensitive policies	Setting of heat exposure limits for conditions in the tropics and individual countries	Dutta et al. 2015
	City and district level monitoring policies	Chen and Huang, 2019
Action plans and warning systems	Heat action plans	Cheng and Huang, 2019; Li et al., 2021
	Heat-health early warning systems and anticipatory public health messaging	Knowlton et al., 2014; Yin and Wang, 2017; Li et al., 2021
Pollution and public health	Pollution monitoring improvements and data gathering to inform policies	Khan et al., 2023
	Transport policies to reduced more polluting vehicles and promote sustainable transport	Khan et al., 2023; Yu et al., 2023
Policies to address the needs of vulnerable groups	Climate Smart Urban Planning to address particular needs of different social groups	Paul et al., 2023
	Targeted education and awareness raising policies	Paul et al., 2023
	Policies to promote information sharing to raise public awareness and knowledge	Khan et al., 2023; Knowlton et al., 2014; Odihi, 2001; Lohrey et al., 2021

The identified papers highlight a critical issue: current health systems are significantly underprepared to address the climate crisis. This significantly impedes their ability to accurately capture and address heat-related illnesses among outdoor workers and sub-groups of outdoor workers such as pregnant women, migrants, and those working in different occupational groups, including outdoor workers in the informal sector.

Yu et al.'s (2023) study highlighted the substantial under-reporting of these health issues, indicating the urgent need for improved surveillance systems. Additionally, the lack of awareness and knowledge about heat-related illnesses among outdoor workers, as evidenced by Khan et al. (2023), points to the necessity for targeted education and training programmes. These programmes need to be tailored to meet the specific needs and circumstances of outdoor workers in different sectors, such as construction or street vending.

The fear of job loss and financial penalties prevents many workers from reporting heat-related symptoms, highlighting the critical role of employers in mitigating these barriers and supporting adaptation. Ko et al. (2020) found that inadequate employer support significantly deterred workers from seeking help for heat-related symptoms. Policies must mandate employers to provide support mechanisms, such as paid sick leave and job security guarantees, to encourage timely reporting and appropriate interventions. Furthermore, the integration of mental health considerations into heat stress management programmes is essential. Liu et al. (2019) emphasised the importance of addressing mental health impacts, which are often overlooked, highlighting the need for comprehensive mental health support alongside physical health measures.

The reviewed studies highlight the urgent need for tailored policies and interventions to protect outdoor workers from the increasing risks associated with climate change, these are outlined below:

Establishing region-specific regulations on heat exposure

Several studies called for the establishment of new region-specific regulations and standards on occupational heat exposure (Dutta et al., 2015; Yin and Wang, 2017; Cheng and Huang, 2019). Current international standards do not provide an accurate indication of limits for heat stress for outdoor workers. The research conducted in India by Dutta et al. (2015) suggested that the heat stress exposure levels for construction workers were higher than those permissible according to international standards. The recorded mean wet bulb temperature was 32.4 ± 1.1°C in summer in Gandhinagar, where the study took place. This was 3.4°C higher than suggested permissible exposure limits for the tropics defined by the ACGIH guidelines[6] (Dutta et al., 2015). The study recommended implementing new guidelines that would provide more accurate heat exposure limits for India and the tropics (ibid.). Similarly, Yin and Wang (2017), suggested developing new standards for heat alerts in China, considering both the temperature threshold and the duration of heat waves. They proposed that heat alerts should be announced when the maximum daily temperature is higher than 35°C for four consecutive days or when the maximum daily temperature is higher than 32°C, 33°C or 34°C for five

6. American Conference of Governmental Industrial Hygienists.

consecutive days. The heat alerts would ensure that medical resources and institutions were prepared for heat stress-related treatment. Additionally, Cheng and Huang's (2019) study in several Asia-Pacific localities, including cities in China, Vietnam, and Thailand, suggested that policy interventions should be developed at city and district levels due to considerable spatial disparity of heat vulnerability.

Developing heat adaptation strategies

Studies recommended developing adaptation strategies, including heat action plans and heat-health warning systems (Cheng and Huang, 2019; Knowlton et al, 2014; Li et al., 2021). Heat action plans might include, for instance, procuring and providing protective equipment, changing work shift times, and paying high-temperature subsidies (Cheng and Huang, 2019). Heat-health warning systems could include weather forecasting, risk communication, and action recommendations for stakeholders who could work on organising medical and public services to address the adverse impacts on public health (ibid.). As Knowlton et al. (2014) recommended, early warning systems could help coordinate the response to extreme heat by mobilising resources and establishing communication channels between multiple actors. In anticipation of extreme heat events, early warning systems would be helpful for disseminating public health messages about protective measures, including reducing outdoor activity, using air conditioning, going to nearby cool centres, wearing light clothing, taking sun protection measures, and drinking more water (Yin and Wang, 2017; Li et al, 2021).

Enhancing air pollution policies and monitoring

Studies reviewed included recommendations for improving air pollution policies and monitoring to address the adverse impacts of pollution on public health (Khan et al., 2023; Yu et al., 2023). Khan et al. (2023) suggested that more accurate public health risk assessments require better and more air monitoring stations to provide the data to inform policies and support implementation. The research also recommended developing green technologies and implementing stricter regulations across sectors and industries. For example, in the transportation sector, vehicle use should be regulated, penalties for violations introduced and policed, the use of public transport and cycling prioritised, and walking promoted through pedestrian-friendly infrastructure (Khan et al., 2023). Similarly, Yu et al. (2023), based on their study in China, suggested reducing and controlling automobile exhaust emissions and coal combustion to limit the concentration of PM2.5, SO2, and NO2 in the air.

Supporting vulnerable communities

The reviewed papers also considered the policy implications that arise from the specific needs of different social groups and communities with varied vulnerabilities to climate change (Cheng and Huang, 2019; Lohrey et al, 2021; Knowlton et al, 2014). Paul et al. (2019) suggest that there is a need for robust Climate Smart Urban Planning to account for the different vulnerabilities of urban communities. Policymakers should develop strategies for strengthening the resilience of the most vulnerable groups. For example, in India, social groups with high adaptive capacity had more knowledge and access to resources to adapt to climate change, highlighting the potential from investment in developing awareness and educating members of the public about climate change adaptation (Paul et al., 2019).

Promoting information sharing and public awareness

Information sharing is central to raising public awareness and knowledge about the health risks posed by climate change (Khan et al., 2023; Knowlton et al., 2014; Odihi, 2001; Lohrey et al., 2021). Knowlton et al. (2014), based on research in Ahmedabad, India, suggested that communicating information about heat stress and associated health risks via media outlets is crucial for public health protection. Similarly, Odihi (2001) advised that governments of the Association of Southeast Asian Nations (ASEAN) should contribute to networking and sharing information about environmental hazards with the public to alleviate the adverse impacts on communities. Likewise, Lohrey et al. (2021) found that there was a need for heat-health education programmes in Hanoi, Vietnam, to raise awareness about health symptoms and climate change risks among social groups under-reporting their health issues, especially construction workers.

Importance of evidence-based policy interventions

Evidence-based policy interventions, informed by multidisciplinary research and stakeholder engagement, are essential to address the complex and interconnected challenges posed by climate change to outdoor workers' health and wellbeing. Collaboration between researchers, policymakers, employers, and community stakeholders is critical to develop and implement effective strategies to protect outdoor workers from climate change-related health risks and promote resilience in the face of environmental change.

Project researcher interviewing a scrap collector at a wholesale market in Ho Chi Minh City, a project research site, July 2024.

4. Implications for research and policy

This review shows that there has been significant progress in recent years as research has paid greater attention to the exposure of outdoor workers to extreme weather. However, there remain knowledge gaps in understanding the complex interactions between employment conditions, environmental stressors, policy interventions, public health outcomes, and socioeconomic conditions.

In this section we provide a summary of these knowledge gaps based on the literature reviewed and discuss the implications of the review for research and policy. Together, they highlight key research priorities necessary for improving health outcomes and interventions for outdoor workers affected by climate change.

Outdoor workers at Cai Rang floating market, selling fresh produce and goods on riverboats, Can Tho, a project research site, December 2024. (Source: Anh Ngoc Vu).

4.1. Knowledge gaps

Incomplete and narrow data collection: Current health systems in many Asian countries are insufficiently equipped to capture the full scope of heat-related illnesses among outdoor workers, resulting in incomplete and inaccurate data. This deficiency hampers our understanding of the true scope of these health impacts.

Limited demographic analysis: There is a significant gap in understanding how climate change uniquely affects different demographic and social groups, such as pregnant women, and migrants. This lack of detailed analysis prevents the development of targeted strategies to protect these vulnerable populations.

Insufficient occupational focus: The health effects of climate change on various occupational sectors, especially informal and lower-wage workers, are inadequately documented. This oversight limits the ability to address the specific risks faced by these workers.

Neglected structural factors: Structural factors that contribute to health vulnerabilities – such as rural-to-urban migration, informal sector employment, and entrenched class, caste, and ethnic disparities – are often overlooked. These deeply rooted issues significantly affect health outcomes but are frequently normalised and inadequately addressed.

Lack of knowledge on non-heat climate hazards: While heat-related health issues are increasingly studied, other extreme weather impacts, such as flooding, cyclones, and co-climatic hazards like landslides and fire-related haze, remain under-researched. The health effects of these events are critical, yet we lack comprehensive studies exploring their impacts on outdoor workers.

Limited exploration of structural explanations of vulnerability: None of the papers reviewed paid attention to the structural factors that create health exposures in the first place. One reason may be because these structural factors are so pervasive and deep-seated that they have become normalised as simply, 'the way things are'. For instance, the drift of millions of rural people to urban work; the prevalence of informal working on casual contracts for the poorest and most vulnerable; and the structures of class, caste and ethnicity that unequally shape opportunities and access. While such structural factors may be ignored because they are viewed as intractable, their nature and significance does vary between countries and they are, therefore, elements in the explanatory mix.

A second issue concerns the ways in which different disciplines and associated methodologies 'frame' the issue. For Mitchell (2002, p.210), "objects of analysis do not occur as natural phenomena but are partly formed by the discourse that describes them" and the "more natural the object appears, the less obvious this discursive manufacture will be". Scholarship on climate change is dominated by research undertaken by the predictive natural sciences, not the critical and interpretative social sciences and humanities. Interdisciplinarity tends to be 'shallow' – between allied disciplines – rather than 'deep', leading to disciplinary reductionism (Rigg and Mason, 2018). Vulnerability to extreme heat then becomes a fact of life, rather than a matter where it is necessary to ask how and why people are placed in such positions – living and working precariously – in the first place.

4.2. Policy implications

Our review identifies the need for targeted policy interventions in the following areas:

Gaps in health system preparedness: Existing health systems are ill-equipped to meet the unique needs of outdoor workers and other vulnerable groups in the face of climate change. This lack of preparedness exacerbates the risks and challenges these groups face.

Need for targeted interventions: There is a critical need for more tailored interventions and policies that address the specific risks associated with different worker groups under changing climate conditions. Current strategies often fail to account for the unique circumstances of these workers.

Lack of comprehensive, integrated frameworks: There is a notable absence of integrated frameworks that address the multifaceted impacts of climate change on health, including environmental and socio-economic factors. While heat-related health effects are well represented in the literature reviewed, other climatic hazards, such as flooding and cyclones, remain less commonly discussed in the literature. Additionally, co-climatic hazards like landslides and fire-related haze, as well as the effects of compound weather extremes, need more attention.

Under-reported health issues: Studies reveal under-reporting of heat-related health issues, highlighting the urgent need for enhanced surveillance systems (Dutta et al., 2015; Wu et al., 2022; Lohrey et al., 2021). A key contributing factor is the lack of awareness and understanding of heat-related illnesses, as many workers fail to recognise symptoms or perceive them as serious health concerns (Lohrey et al., 2021; Dutta et al., 2015).

This emphasises the need for targeted education and training programmes that are both accessible and tailored to the specific needs of outdoor workers. These programmes should account for socio-demographic variations, including the needs of younger and older workers, pregnant individuals, and those with pre-existing health conditions. To maximise accessibility and effectiveness, these initiatives should provide information in local languages, accommodate varying literacy levels, and reflect the cultural and practical realities of the workers they aim to support.

Health systems adaptation: The need for health systems to adapt in response to climate change is another critical area for future research. Health sectors must build the capacity to collaborate on prevention and response efforts, ensuring they are equipped to address the increasing health challenges posed by climate change. Understanding how health systems can be strengthened to support such collaborations is vital for enhancing public health resilience.

Individual and systemic coping strategies: The coping strategies employed by outdoor workers to mitigate the adverse effects of extreme heat and pollution are diverse and multifaceted. While strategies such as hydration, protective clothing, altered work hours, community support, and technological interventions are beneficial, studies indicate that these measures are often insufficient when used in isolation. There is a critical need for integrated approaches that combine these strategies with broader systemic changes, including improved urban planning, stricter environmental regulations, and enhanced healthcare access. Future research should focus on developing and testing innovative solutions that provide comprehensive protection for outdoor workers, ensuring their health and safety in increasingly extreme environmental conditions.

4.3. Future research directions

These gaps highlight several key areas for future inquiry. At the broadest level, there is a need for:

- **Interdisciplinary and longitudinal research:** Understanding the exposure of outdoor workers requires interdisciplinary approaches that utilise mixed methods and longitudinal and spatial analyses. There is broad recognition that outdoor workers are particularly vulnerable to extreme weather, but the detail of how this is manifested is less well understood. How does exposure vary? What strategies do workers take to mitigate the effects of extreme weather? What constrains or limits such actions? How effective is government policy in supporting workers in their efforts? Do employers support or constrain such efforts? Additionally, there is a need for more comprehensive monitoring and evaluation of environmental health interventions to inform evidence-based policy-making and adaptive strategies (Dutta et al., 2015).

More specifically, this systematic evidence review points towards the need :

- **Spatial analyses and nexus thinking:** There is a need for studies that utilise spatial analyses to explore the synergies between environmental sustainability, public health, and social equity. Adopting 'nexus thinking' – an approach that considers the interconnectedness of climate impacts, health, and structural drivers – is essential. Existing studies rely mainly on quantitative methods, not infrequently from secondary sources that are unsuited to the detailed analysis necessary to understand the issue, and not just to gauge its extent. Qualitative studies, when included, are frequently subsidiary to the quantitative elements of the research and lack depth in methodological engagement. This highlights the need for more robust and integrative qualitative approaches to complement spatial and quantitative analyses effectively.

- **Effectiveness of heat stress interventions:** Research should focus on evaluating different heat stress intervention strategies, such as hydration protocols, rest break schedules, and cooling technologies. Comparative studies in various work environments can help identify the most effective approaches for protecting outdoor workers. Additionally, there is a pressing need to address the under-reporting of health issues, particularly the mental health impacts of heat stress (Liu et al., 2019).
- **Socioeconomic and structural drivers:** Future research must delve deeper into the socioeconomic factors that exacerbate heat vulnerability. Understanding how income levels, age, gender, educational attainment, job security, and healthcare access influence health outcomes is crucial (Ko et al., 2020). Moreover, greater attention should be given to the structural drivers – historical, political, and economic factors – that shape policy uptake and implementation.
- **Cultural and behavioural influences:** Investigating cultural and behavioural factors that affect the reporting of heat-related illnesses is important to inform the design of culturally sensitive interventions. What works well in one cultural context might not be so effective in another. Studies should explore how cultural norms and beliefs impact health-seeking behaviour and adherence to preventive measures (Cheng and Huang, 2019).

A meeting with Vietnam Medical Association, our project local partner in Hanoi, May 2024.

ANNEX A: Methodological Approach

A.1. Development of search strings

Our search strings combined terms related to two broad areas: climate change and climate variability; and health and health outcomes. To minimise bias and identify lesser known or understudied health impacts on marginalised and vulnerable populations, the search strings were intentionally broad. They were continuously and critically refined through a series of internal team discussions.

The search strings built upon the research questions that underpinned the research, as follows:

- What are the health impacts of the weather extremes associated with climate change for outdoor workers in urban Asia?
- What types of extreme weather impact the health of outdoor workers in urban Asia?
- What forms of outdoor working and categories of outdoor workers are most health exposed to weather extremes in urban Asia?
- What are the coping strategies and adaptive capacities of these groups? In what ways does the state provide assistance to build resilience and support such coping strategies?

We utilised Boolean operators and key concepts pertinent to the review. These covered the themes of Climate, Health, Work, Social, Urban and Asia (Table A1). Research Question 1 focuses on identifying the health impacts of the weather extremes associated with climate change for outdoor workers in urban Asia. To identify and capture existing literature relating to this health-focused research question, we included a combination of search terms, including: 'health', 'disease', 'infectious', 'morbidity', 'wellbeing', 'quality of life', 'mortality', and 'death'. These terms were selected based on the findings from previous studies undertaken by the research team and following a preliminary survey of the literature to help guide the selection of search terms.

Research Question 2 pays attention to 'climate' and the types of extreme weather impacting the health of outdoor workers in urban Asia. The search terms selected here included 'climate', 'weather', 'flood', 'drought', 'heatwave', 'heat', 'cold', 'global warming', and 'hurricane'.

Research Question 3 focused on the 'work' category of the project and here we sought to identify forms of outdoor employment where workers are exposed to weather extremes. The selected search terms included 'outdoor work', 'porter', 'construction', 'vendor', 'street vendor', and 'rider'. We further refined the search by adding a 'social' category to capture the project's interest in the social vulnerabilities of worker groups. To this end, the search terms included such themes as 'gender', 'age', 'elderly', and 'poverty'. Finally, to ensure a geographical focus to the literature search, we included a range of terms to capture the 'Urban' and 'Asia' concerns of the project. We also undertook country-by-country searches to ensure that studies that did not have the keyword 'Asia' would be captured by the review.

Table A1. Search strings

Component	Search strings
Climate	Climat* OR weather OR flood* OR drought OR heatwave OR heat OR cold OR global warming OR hurricane OR typhoon OR monsoon OR rainfall OR adaptation OR mitigation OR greenhouse gas OR storm OR cyclone OR coastal erosion OR risk OR natural disaster OR wildfire
Health	Health OR disease OR infectious OR morbidity OR wellbeing OR quality of life OR mortality OR death OR accident OR wellbeing OR injur* OR hospital* OR mental OR medical* OR emergency OR stroke OR maternal OR exhaustion OR cramp OR pregnan* OR fever* OR fatigue OR burn OR stress OR skin
Work	Outdoor work* OR porter OR construction OR vendor OR street vendor OR rider OR outdoor occupation
Social	Gender OR age OR generation OR old OR young OR elderly OR poverty OR exclusion OR precari* OR migrant OR minority OR vulnerabl* OR informal* OR casual* OR contract* agreement
Urban	City OR cities OR town OR urban OR metropolitan
Asia	Asia OR Vietnam OR China OR Timor Leste OR East Timor OR Indonesia OR Philippines OR Cambodia OR Thailand OR Laos OR Lao PDR OR Myanmar OR Burma OR Malaysia OR Brunei OR Brunei Darussalam OR Mongolia OR India OR Sri Lanka OR Nepal OR Pakistan OR Bangladesh OR Bhutan OR Afghanistan OR North Korea OR Democratic People's Republic of Korea

A.2. Development of inclusion/exclusion criteria

Inclusion and exclusion criteria were developed for each piece of evidence to be assessed against (Table A2). The papers were screened for eligibility at title, abstract and full-text levels using inclusion and exclusion criteria set out at the start of the study. The review limited itself to academic research papers published in the English language since 2000, including systematic literature reviews, scoping reviews, rapid evidence assessments, meta-analyses, narrative analyses, relevant grey literature, and qualitative, quantitative and mixed methods studies. The scope of the review was limited to papers that focused on climate change and its health impacts for workers in urban Asia. Additionally, papers on the impacts of climate change adaptation and mitigation on the health and wellbeing of workers were included in the review. Sources where climate change impact on the health of workers was not a dominant focus were excluded, as were articles that concentrated on rural areas or areas outside of Asia. Opinion pieces and popular media such as blogs, social media feeds or newspaper articles were also excluded from the review.

Table A2. Inclusion and exclusion criteria

Criterion	Inclusion	Exclusion
Content	• Research on climate/weather change and events and health impacts with a focus on workers (especially outdoor workers) in urban Asia • Research on the impacts of climate change adaptation and mitigation on health/ wellbeing	• Studies with a rural focus • Studies outside Asia • Papers on the climate impacts on health and wellbeing (e.g. dry/cold//humid climates) (i.e. these papers simply focus on climate, not climate change-related weather shifts) • Research on the impacts of those indoors
Types of literature	• All research papers, including systematic literature reviews (including scoping reviews, rapid evidence assessments, meta-analyses, narrative analyses) • Relevant grey literature • Quantitative and qualitative studies	• Opinion pieces • Popular media (e.g. blogs, social media feeds, newspaper articles)
Date of publication	January 2000 – April 2024	Research published before January 2000
Geography	Studies from urban + Asia	Research not from urban + Asia
Language	English	Not English

A.3. Pilot search and identification

To test the strength of the search strings and inclusion and exclusion criteria, and to determine the best databases to search, pilot searches were conducted on Google Scholar, Scopus, PubMed, and Web of Science.

A.4. Full database search and screening

The approach to identifying evidence involved a structured search of three academic databases: Scopus, the Web of Science, and PubMed. Drawing on our prior experience and based on a preliminary scoping review, we used the year 2000 as the starting year for this systematic evidence review. This timeframe, we judged, allowed for the inclusion of both foundational studies and recent research, offering a comprehensive overview of the literature on the topic. To reassure us that we would not be unintentionally omitting important literature, we undertook preliminary searches covering the period before 2000; these did not produce a significant number of results confirming that 2000 was an appropriate year to begin our search of the literature.

The process of screening and making decisions on including or excluding documents involved multiple stages. We input the search strings into Scopus, the Web of Science, and PubMed and received the following results: 417 papers from the Scopus search, 222 papers from Web of Science, and 95 papers from PubMed (Table A3).

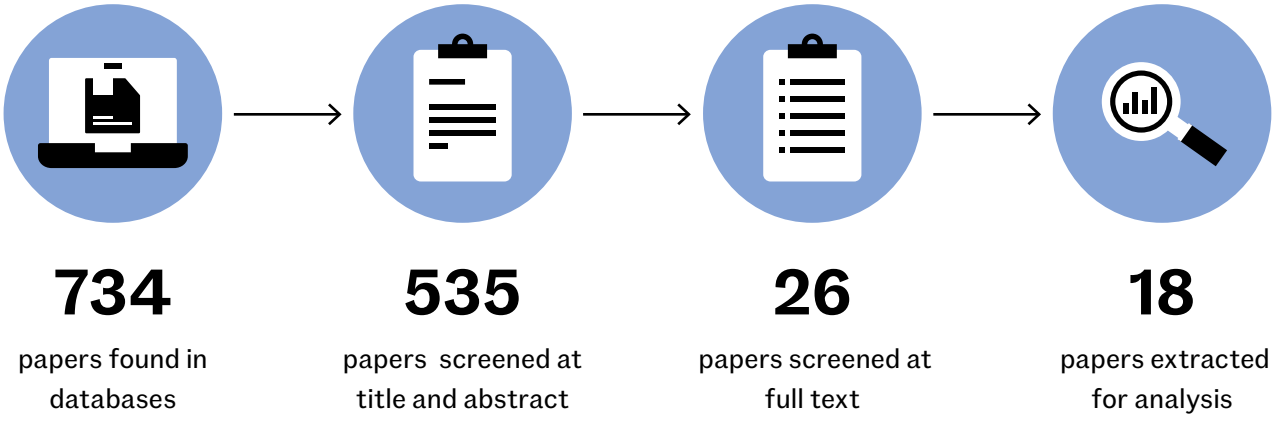
The documents were uploaded into Covidence, a software programme for managing systematic reviews, for manual screening at title and abstract levels, followed by full-text review. To begin, duplicates were removed, leaving 479 papers for title and abstract screening. Two reviewers screened each paper's title and abstract and voted for each paper based on the inclusion and exclusion criteria. The reviewers could choose between three answers: 'Yes', 'Maybe' and 'No'. We voted 'Yes' for papers that met eligibility criteria and 'No' for articles that did not satisfy the criteria. When reviewers were not able to decide on the relevance of a paper, the reviewers chose the 'Maybe' answer, which was essentially treated as a 'Yes' vote at the title and abstract screening stage. All voting was blinded, and a reviewer did not see a vote of another reviewer until they provided their own vote. In a few cases, when reviewers gave different votes for the same papers, those sources were included for the subsequent review at full text level. This process yielded

26 papers identified as relevant after the title and abstract screening. The reviewers screened those papers at full text, referring to the inclusion criteria. Consequently, eight papers were excluded from the review, and 18 papers were identified as relevant and extracted from for the following data analysis (Figure A4). For one article, the research team could not access the full text so it was excluded from the review.[7]

Table A3. Number of search results

Component	Inclusion	Exclusion	PubMed
Climate	8,284,985	5,710,208	3,059,869
AND Health	4,175,645	2,338,655	1,952,061
AND Work	44,224	23,130	8,008
AND Social	10,306	5,626	2,452
AND Urban	1,450	778	202
AND Asia	417	222	95

Figure A4. Flow diagram of the screening process



7. Gupta R K (2021) A study on occupational health hazards among construction workers in India. International Journal of Enterprise Network Management (IJENM), Vol. 12, No. 4.

A.5. Data extraction

After full-text screening, 18 articles were extracted from using a data extraction tool. The data extraction tool allowed for data to be organised in a tabular form: it comprised of rows representing the papers reviewed and columns representing the key themes.

Themes were developed based on the research questions and the themes that emerged from the literature (Table A4). Each theme comprised several subthemes that represented the columns in the extraction document. This tabular form of presenting data ensured efficiency when interpreting it, as it linked papers' summaries to the research questions and allowed the evidence for a single research objective to be easily found and viewed. Additionally, the extraction document enabled reviewers to return to original sources if summaries were unclear or more information was needed.

A discussion with a community-based organisation, a local project partner in Can Tho, one of the project sites in May 2024.

Table A4. Data extraction framework: column groups and columns

Themes (column groups)	Sub-themes (columns)
Article reference	Author(s)
	Title
	Date (year)
	Journal / Source
	Full reference
Methodology and abstract	Abstract
	Summary of key findings and arguments
	Methods used
	Themes covered in depth
	Demographics of the sample
	Country of focus
Health impacts of weather extremes for outdoor workers	Health impacts – Type
	Health impacts – Severity
	Nature of societal vulnerabilities identified
	Impacts of climate adaptation/mitigation
Types of extreme weather impact on the health of outdoor workers	Extreme weather – Type and Forms
Forms of outdoor working that are most health exposed to weather extremes	Outdoor work – Types
	Outdoor work – Social groups
Coping strategies	What coping strategies are adopted to escape from weather extremes
	What coping strategies are adopted to adapt to weather extremes
Policy actions and recommendations	Actions
	Recommendations
Reflections	Gaps and limitations
	Suggestions for future research

A.6. Summary of the 18 papers reviewed

Table A5. Summary of the 18 papers

Paper (authors and date)	Methods	Geographical coverage	Climate change(s)	Health impacts
Ayyappan, R; Sankar, S; Rajkumar, P; Balakrishnan, K (2009)	Mixed methods study	India	Heat	Heat stress
Cheng, L and Huang, C (2019)	Quantitative study	China, Vietnam and Thailand	Extreme temperature	Work-related injuries and work-related injuries
Dutta P, Rajiva A, Andhare D, Azhar GS, Tiwari A, Sheffield P, Ahmedabad Heat and Climate Study Group (2015)	Mixed methods study	India	Extreme heat	Heat stress
Hidalgo, H.A.; Cuesta, M.A.; Razafindrabe, B.H.N. (2022)	Mixed methods study	Philippines	Typhoon	
Jim, C Y and Yang, F Y (2006)	Quantitative study	China		Environmental degradation, farmland inundation
Khan, RH; Quayyum, Z; Rahman, S (2023)	Quantitative study	Bangladesh	Air pollution	Respiratory diseases, chronic respiratory illness, reduced lung function development, and asthma
Knowlton K, Kulkarni S, Azhar G, Mavalankar D, Jaiswal A, Connolly M, Nori-Sarma A, Rajiva A, Dutta P, Deol B, Sanchez L, Khosla R, Webster P, Toma V, Sheffield P, Hess J and the Ahmedabad Heat and Climate Study Group (2014)	Mixed methods study	India	Extreme heat	Heat stress, hospitalisation, mortality

Ko, TK; Dickson-Gomez, J; Yasmeen, G; Han, WW; Quinn, K; Beyer, K; Glasman, L (2020)	Qualitative study	Myanmar	Environmental pollution, heavy monsoon rains	Respiratory infections, chronic obstructive pulmonary disease (COPD), lung cancer, tuberculosis, asthma, cardiovascular diseases
Lashari A, Kazi T G, Afridi H I, Baig J A, Arain M B, Lashari A A (2024)	Quantitative study	Pakistan		Respiratory and liver disorders, immune toxicity, neurotoxicity, lung cancer, kidney disorders
Li, ZX; Hu, JX; Meng, RL; He, GH; Xu, XJ; Liu, T; Zeng, WL; Li, X; Xiao, JP; Huang, CR; Du, YD; Ma, WJ (2021)	Quantitative study	China	Hot extremes	Mortality, heatstroke, heat cramp, acute cerebrovascular accidents
Liu X; Liu H; Fan H; Liu Y; Ding G (2019)	Quantitative study	China	Extreme heat	Mental illness
S. Lohrey, M. Chua, C. Gros, J. Faucet, J.K.W. Lee (2021)	Mixed-methods study	Vietnam	Extreme heat	Heat cramps, heat exhaustion and heat stroke
Odihi, J.O. (2001)	Mixed methods study	Brunei Darussalam	Haze	Bronchial disorders, chronic obstructive pulmonary diseases, pneumonia, conjunctivitis and acute upper respiratory tract infections
Paul A, Deka L, Gujre N, Rangan L, Mitra S (2019)	Quantitative study	India	Heat, floods, drought	Heat stroke
Sheng, R., Li, C., Wang, Q., Yang, L., Bao, J., Wang, K., ... & Huang, C. (2018)	Quantitative study	China	Heat	Work-related injury
Wu C, Shui W, Yang H, Ma M, Zhu S, Liu Y, Li H, Wu F, Wu K and Sun X (2022)	Quantitative study	China	Extreme heat	Heat stroke
Yin, Q and Wang, J (2017)	Quantitative study	China	Heat waves	Cardiovascular disease, mortality
Yu, DZ; Lee, SB; Chen, S; Kim, SW; Xi, SS (2023)	Quantitative study	China	Extreme temperatures and air pollution	Non-accidental deaths

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Street vendor braving heavy rain, selling flowers on a bustling roadside, Hanoi, September 2024. (Source: Project team in Hanoi).

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